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SAFETY CONTROL OF THE SPIRAL2 RADIOACTIVE GAS STORAGE SYSTEM

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Abstract

The phase 1 of the SPIRAL2 facility, extension project of the GANIL laboratory, is under construction and the commissioning has started. During the run phases, radioactive gas, mainly composed of hydrogen, will be extracted from the vacuum chambers. The radioactive gas storage system function is to prevent any uncontrolled release of activated gas by storing it in gas tank during the radioactive decay, while monitoring the hydrogen rate in the tank under a threshold. The confinement of radioactive materials is a safety function. The filling and the discharge of the tanks are processed with monostable valves, making the storage a passive safety system. Two separate redundant control subsystems, based on electrical hardware technologies, allow the opening of the redundant safety valves, according to redundant pressure captors, redundant di-hydrogen rate analyzers and limit switches of the valves. The redundancy of the design of the control system meets the single failure criterion. The monitoring of the consistency of the two redundant safety subsystem, and the non-safety control functions of the storage process, are then managed by a Programmable Logic Controller.

INTRODUCTION

The SPIRAL2 facility, in the GANIL laboratory, will produce high-intensity ion beams for experimental nuclear physics. The accelerated ions will go from hydrogen to heavier ions such as carbon, argon or nickel. During the Phase 1, the ion beams are accelerated in the LINAC and sent to experiment rooms, S^3 (Super Separator Spectrometer) and NFS (Neutrons For Science), through the high-energy lines vacuum chambers. The extracted gas, coming from the impact of the beam on the beam stop, or from the degassing of the vacuum chambers, are radioactivated and have to be stored and monitored. This extracted gas is expected to be mainly composed of dihydrogen, as shown in Table 1.

Table 1: Extracted Gas Composition

Component	Rate at the start of the irradiation	Rate at the end of the irradiation
Dihydrogen	17 %	52 %
Water	69 %	43 %
Nitrogen	4 %	4 %
Carbon dioxyde	10 %	1 %

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Table 2: Expected Gas Volumes

Origin	Volume (litre/5 days)	H_2 volume (litre/5 days)
LINAC	9.6	7.8
NFS	1.4	1.2
S^3	7.2	5.8

After a predefined length of time, estimated at two to five days, the radioactive decay is checked and the gas is released into the environment.

MAIN FUNCTIONS OF THE STORAGE CONTROL SYSTEM

Protection Functions

The tanks of the radioactive gas storage system are the first containment barrier. To prevent any risk of dissemination, the system fulfills two protection functions, regarding two accidental events [2]:

- The uncontrolled release of activated gas towards the chimney of the nuclear ventilation system.
- The leak of a tank or a pipe, or the burst of a tank because of an excess of hydrogen rate in the tank.

The storage system is made of two tanks which will be filled one at a time, while the other one is isolated for its radioactive decay. The system is designed to add a third tank if needed. The dimension of their volume, 1.6 m^3, was calculated to allow an uninterrupted filling of one tank during the decay of the other one, while diluting the gas being stored to prevent any risk of burst caused by the hydrogen.

To prevent risks of leaks, the whole storage system, tanks and pipes, is working under low pressure. The tanks are jacketed, and the space between the two layers is maintained under slightly high pressure to prevent gas leaks towards the outside of the tanks. In the same way, the hydrogen rate analyzer systems are set up in low pressure ventilated boxes. A pump and a flow controller maintain an adequate flow into the hydrogen analyzers.

The Storage Control Phases

The process cycle of each tank is composed of several phases, illustrated in Figs. 1, 2 and 3. Only one phase is running at a time on each tank.

- The filling stage: The tanks are empty at first, at a pressure of 1mbar. The input valves of the tanks are opened to allow the gas in, until a maximal pressure of 0.95 bars. The tank is then considered full. During the filling phase, a hydrogen rate ana-

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lyzer system measures the hydrogen rate in the tank. The gas is diluted with air to keep the hydrogen rate under 1%, this threshold being 25% of the flammability limit. If the hydrogen rate still goes over 2%, the filling is interrupted.

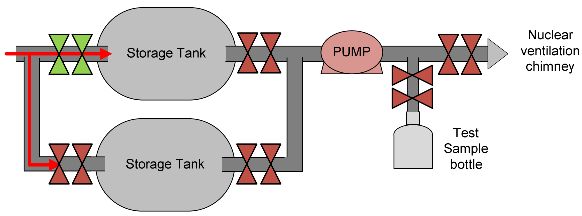

Figure 1: Filling phase.

- The isolation phase: the input and the output valves of the tank are closed during the length of time of the radioactive decay, estimated to a few days. During this phase all the safety valves are closed, making it a safe situation.
- The sampling phase: the output valves of the tank are opened, as well as the sampling valves at the input of a 10L sample bottle. The test sample will be analyzed by the Radiation Protection team of the GANIL. They will determine whether the decay is adequate to allow the release of the stored gas into the environment, or if the decay needs more time.

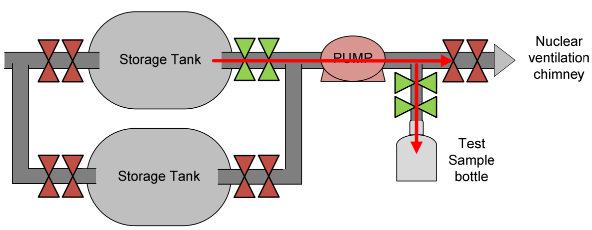

Figure 2: Sampling phase.

- The emptying phase: the output valves of the tanks are opened, as well as the valves of the nuclear ventilation chimney. A pump is started to transfer the gas into the environment, emptying the tanks to a low pressure of 1mbar. This phase must be specifically allowed by the Radiation Protection team of the GANIL, and by the operations supervisor of the SPIRAL2 facility.

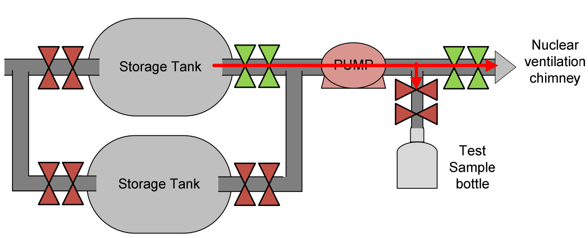

Figure 3: Emptying phase.

ARCHITECTURE OF THE SAFETY CONTROL SYSTEM

The FMEA with Single Failure Criterion

The radioactive gas storage system being a safety system, its control system is a safety system as well.

A Failure Mode and Effects Analysis (FMEA) was made to eliminate dangerous failure [1]. The single failure criterion was selected as reliability criterion. The FMEA shows the necessity of the redundancy of the safety items and of the safety control, so that a single failure does not harm the global protection function of the safety system. The whole control chain is doubled, from the sensor to the actuator. The two subsystems, called A and B, are segregated and dissimilar to avoid common-mode failure risks. The safety control system is based on electrical hardware technologies, such as relays with forcibly guided contacts respecting the EN50205 standard, making it a robust and dependable control system. This design also makes the FMEA clear and determinist. The system, thanks to its monostable valves and its relays, is designed to be a passive safety system.

During the life of the facility, the system will be periodically inspected to avoid any multiple failures.

Two Hardware Redundant Safety Subsystems and a PLC

On top of the safety control system based on hardware technologies, a PLC (Programmable Logic Controller) fulfills the non-safety control, and is also necessary to open the safety valves [3]. Both the safety control system and the PLC have to be consistent for the safety valves to open, otherwise, they stay closed, as shown in Fig. 4.

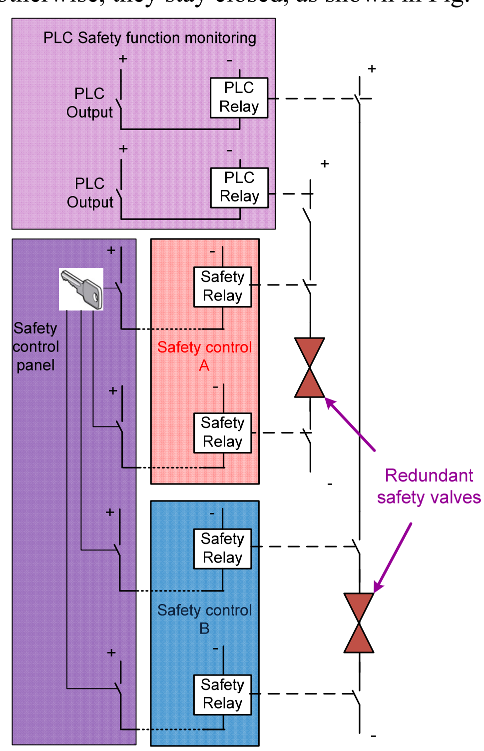

Figure 4: Electrical command of the safety valves.

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The PLC is composed of two CPUs (Central Processing Unit): one is dedicated to the monitoring of the consistency of the two redundant safety subsystems, and the other one manages non-safety functions of the storage process (see Fig. 5). Those two CPUs communicate with each other through a dedicated network, independent from the global network of the facility.

For maintenance purpose, and to make a potential evolution of the non-safety process easier, the non-safety control system is separated from the two safety control subsystems, which are settled in protected electrical control boxes.

The PLC can also be used during the test of the safety control subsystems. The outputs of the PLC are connected to the inputs of the safety control system, and positioned at will from a HCI screen to simulate the state of the storage system. It allows checking the safety control system response to any commands and any failure.

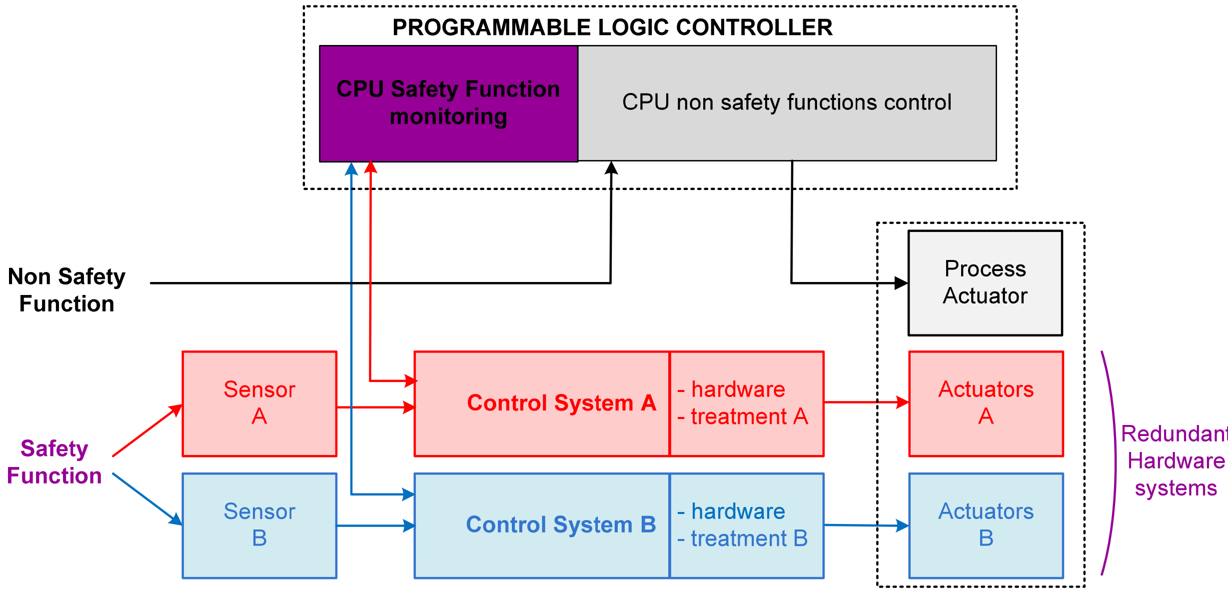

Figure 5: Safety control and non-safety control architecture.

DISTRIBUTION OF THE FUNCTIONS

Safety Electrical Control Boxes

The safety controls are distributed among different electrical control boxes, called A, B, C, D, and G (see Fig. 6).

A and B The safety electrical control boxes A and B forbid:

- The simultaneous opening of the output and input valves of each tank.
- The simultaneous opening of the input valves of two different tanks.
- The simultaneous opening of the output valves of two different tanks.

A and B monitor the pressure level and the hydrogen rate in each tank. If those measures are over a threshold, or if a sensor is defective or unavailable, the tanks are withdrawn to a safe situation: the current phase is interrupted and all the valves of the faulty tank are closed.

C and D The safety electrical control boxes C and D, located in a different place than A, B, and the tanks, forbid the simultaneous opening of the sampling valves and of the valves of the nuclear ventilation chimney. They also check the adequate position of the test sample bottle and the authorization of release given by the Radiation Protection team and the operation supervisor.

G The phases controls are given from a safety control panel, in box G, with keyed switches and luminous hardware indicators.

PLC Electrical Control Box

The PLC is contained in the electrical control box F, segregated in two parts, one for the safety function monitoring CPU, and the other part for the non-safety control CPU. This CPU manages the non-safety control such as the dilution of the stored gas, the monitoring of the flow through the hydrogen analyzers, the displaying of analog measures. It also communicates with other systems of the facility, which need to know whether the storage system is ready or not: the vacuum system to allow the vacuum chambers pumps to work, and the general accelerator Interlock to allow the beam in the LINAC and the experiment rooms. The PLC also reports events to the Alarm Reporting System, when a phase has ended or when a failure appears.

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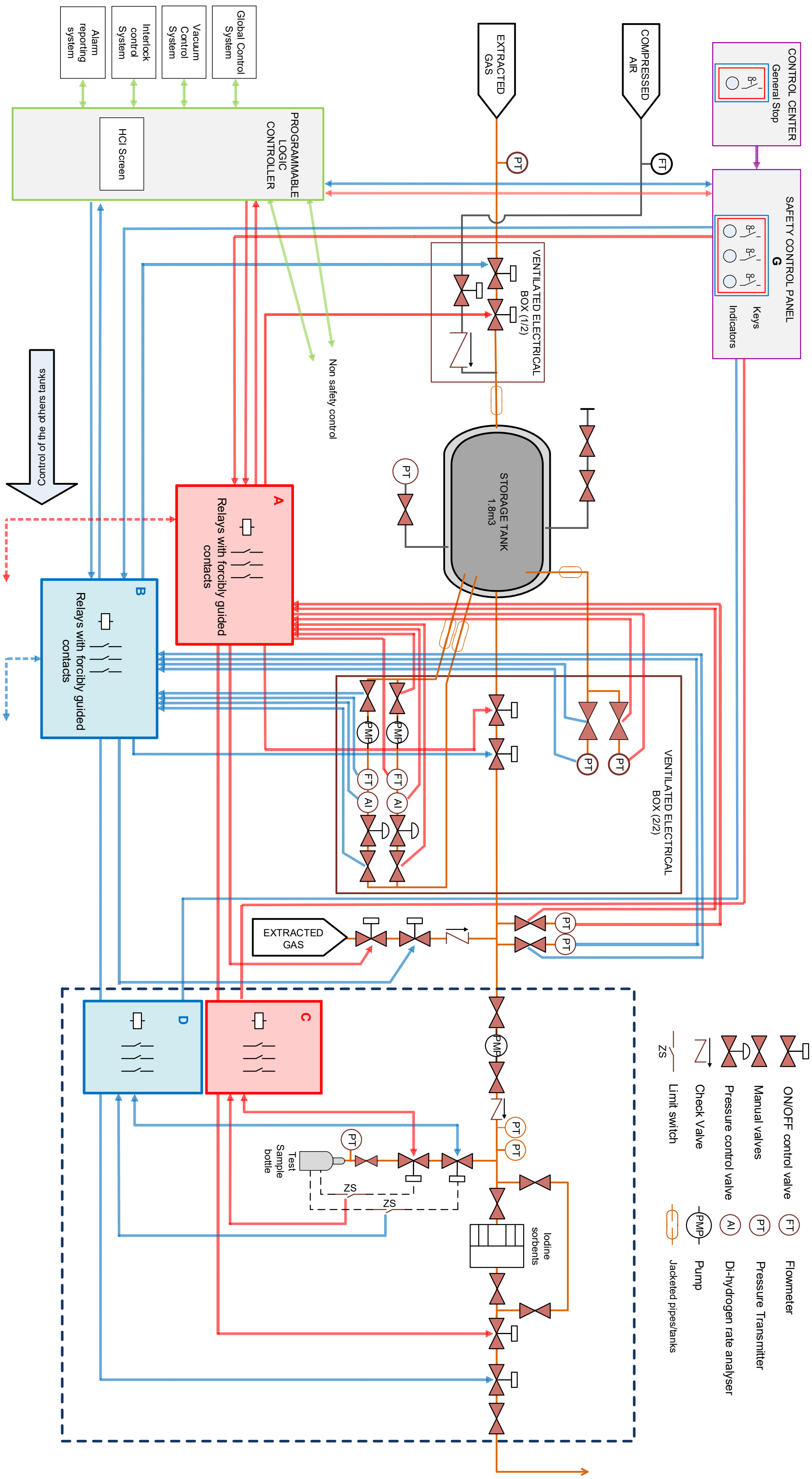

Figure 6: Layout of the control of one storage tank.

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CONCLUSION

Safety aspects of a control system imply a much heavier workload, due to quality constraints associated with safety class equipment. This work has been achieved for the safety control system. The safety electrical control boxes have been successfully developed, tested and set up in the SPIRAL2 facility.

The tanks and pipes have recently been installed too. On this day, the programming of the storage system PLCs and high-energy lines vacuum systems PLCs is going. Tests and adjustments of the whole storage system will be conducted during the first semester of 2018, including safety tests necessary to bring the SPIRAL2 accelerators into full operation.

REFERENCES

[1] L. Gerard, “AMDE du système de commande sécurisé du système d’entreposage des gaz de pompage”, GANIL, Caen, France, Rep. ATRIUM-98970, 2016.

[2] A. Savalle, “Entreposage des Gaz de pompage SPIRAL2 Phase1, Analyse de sûreté”, GANIL, Caen, France, Rep. I-33130v2, June 2013.

[3] Q. Tura, “Entreposage des gaz de pompage SPIRAL2 Phase1, Mémoire explicatif du système de commande”, GANIL, Caen, France, Rep. I-041526v2, July 2015.